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Center for Building Technology
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U. S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary

NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

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EXTERIOR WALLS FOR SINGLE FAMILY HOUSING

by

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ABSTRACT

As a part of the testing and evaluation activities in Operation BREAKTHROUGH, a standard fire test conforming to ASTM E 119 was performed at the National Bureau of Standards on a wall assembly where half represented a nonbearing single exterior wall (as found in single family detached housing) and the other half represented a nonbearing double wall assembly for an interdwelling separation which would occur at the interface of two parallel adjacent modules. Each wall contained a layer of gypsum board as an interior (room) surface and a layer of plywood as an exterior surface, and was framed with nominal 2 x 4 in. wood studs on 16 in. centers. No structural load was applied during the test.

The fire endurance of the single wall was 43 min. The initial mode of failure was by excessive average temperature rise on the unexposed surface of the wall.

Although the test results of the interdwelling wall were inconclusive, its fire endurance was considered to be 1 hr 02 min. This fire endurance was based on visual observation during the test and was the time when the gypsum board on the unexposed side was observed to separate from the wood studs.

Key Words: Fire endurance; Fire test; Housing systems; Interdwelling wall; Operation BREAKTHROUGH; Single wall

TABLE OF CONTENTS

1.0 INTRODUCTION

Several modular systems proposed for the Operation BREAKTHROUGH Program were constructed such that the sides of adjacent modules formed an interdwelling double wall which was required to be a fire barrier. Since information was not available on the fire resistance of double wall constructions as compared directly with single wall construction it was necessary to perform fire endurance tests. In the test assembly, the interdwelling double wall was composed of the following sequence of materials: Gypsum board or plaster, wood or steel studs, plywood, air spaces, plywood, wood or steel studs, gypsum or plaster. The gypsum board or plaster forms the interior or room side of the module, while the plywood forms the exterior side.

A standard fire test was performed on a combined single and double wall configuration, in which one-half of the assembly represented a modular double wall and the other half a conventional (single) wall to determine the difference in fire endurance between them. The fire exposure followed the requirements of the Standard Methods of Fire Tests of Building Construction and Materials, ASTM E 119[1/].

2.0 CONSTRUCTION

The first wall, which was 8 ft high x 16 ft wide, was mounted into a wall test frame in the NBS panel furnace. A second wall, which was 8 ft high x 8 ft wide, was added on the unexposed side at the south end of the test frame, parallel to the first wall, forming a double wall section with a 2-3/4 inch air space between the two walls. Each wall

1/ Standard Methods of Fire Tests of Building Construction and Materials, American Society for Testing and Materials Designation E 119-70, available at 1916 Race Street, Philadelphia, Pa. 19103

assembly consisted of a single layer of 5/8 inch Type X gypsum board as an interior (room) surface and a single layer of 1/2 inch grade A-C plywood as an exterior surface nailed to 2 x 4 inch (nominal) wood studs on 16 inch centers. On the double wall section the gypsum board sides faced the furnace and the testing room, while the plywood sides faced the air space. Nominal 2 x 4 fire stops were placed in two stud spaces of the first panel and in one stud space of the second panel at the mid-height of the assembly. See Figure 1 for the details of the framing and closures between the wall panels.

Since the 8 ft height of the specimen was less than the 10 ft height of the test frame, a filler designed to have sufficient fire endurance and rigidity during the test was placed at the bottom of the specimen. The filler was made up of 2 x 12 lumber and protected on the fire-exposed side with two layers of 5/8 inch Type X gypsum board and sprayed with fire protective vermiculite plaster on metal lath. The unexposed side was covered with a single layer of 5/8 inch Type X gypsum board.

3.0 INSTRUMENTATION

The instrumentation consisted of 32 thermocouples, a deflection indicator, and pressure measuring device. The thermocouples, Chromel-Alumel (Type K), were installed as follows: 8 thermocouples in the stud space with a fire stop and the adjacent stud space of the first panel; 8 surface thermocouples and 4 thermocouples on the plywood board (unexposed surface of the first wall); 4 thermocouples in the air space between the two wall panels; 4 thermocouples in the stud space with a fire stop and the adjacent stud space of the second panel; and 4 surface

thermocouples on the unexposed surface of the second wall. The surface thermocouples were placed under standard 6 x 5 in. felted asbestos pads. Figure 1 shows the locations of thermocouples. The photograph in Figure 2 shows the unexposed surface of the specimen and the connections of the thermocouples.

The deflection indicator consisted of a wire which was strung horizontally across the center height of the specimen. At the start of the test the wire was 3-1/4 in. from the double wall surface and 8-1/4 in. from the single wall surface. The variation of the distance from the wire to the wall surfaces was measured at the center of each wall periodically by means of a ruled measuring device during the test.

The pressure measurement within the furnace was made with a disk type probe connected to a differential pressure transducer with tubing. The probe consisted of 1/8 in. inside diameter stainless steel tubing attached to the edge of a 1-1/8 in. diameter metal disk having rounded edge and connected to a small hole in the center of the disk. The disk was positioned so that the hole was normal to the upward flow of gas.

4.0 TEST PROCEDURE

The furnace temperature was measured by 12 thermocouples which were equally distributed within the furnace. These thermocouples were enclosed in sealed, standard weight, 1/2 in. diameter black iron pipe. The furnace temperature, which was constrained to follow the standard ASTM E 119 temperature-time curve by manual control of the gas flow to the burners, is shown in Figure 3. The temperatures of the thermocouples were printed out at 2 minute intervals on a data logger from which they were punched onto cards for processing and plotting by computer.

Since the assembly represented nonbearing construction, no structural load was applied. The details of the wall furnace with typical wall assembly in place are shown in Figure 4.

The test was run with the furnace neutral pressure point located at one-third height above the bottom of the specimen.

5.0 TEST EVALUATION

The fire endurance of a nonbearing construction is the time required to reach the first occurrence of any one of the criteria of failure, which are as follows:

a. The assembly shall have maintained its integrity during the fire endurance test without passage of flame or gases hot enough to ignite cotton waste, for a period equal to that for which classification is desired.

b. Transmission of heat through the assembly during the fire endurance test shall not have been such as to raise the average temperature on its unexposed surface more than 250°F (139°C), or 325°F (181°C) at one point above its initial temperature.

A test shall be regarded as successful if the above conditions are met.

6.0 TEST RESULTS

A log of the test observation is given in Appendix I. The fire endurance of the single wall was 43 min and that of the interdwelling double wall was considered to be 1 hr 2 min.

6.1 SINGLE WALL

The failure of the single wall due to an average temperature rise of 139°C above its initial temperature on the unexposed surface was observed at 43 min (see Figure 5). Flame penetration was observed at the top of the vertical joint separating the single and double wall portion of the assembly at 47 min and the gas supply to the furnace was discontinued. At this time the air temperature in the stud space of the first wall was over 600°C (1112°F) and increasing rapidly. Direct flame-through of the plywood surface of the first wall occurred at 51 min. Figures 6 and 7 show the location of the flame-through just before and after the instant of the flame-through. In Figure 6, gray smoke is visible at top of the double wall portion.

6.2 DOUBLE WALL

The average temperature rise of the unexposed surface of the double wall at 43 min was 15°C (27°F). The average unexposed surface temperature rise and average temperature rise vs. time across the double wall are shown in Figure 8. A comparison of the average temperature rises of three groups of thermocouples on the unexposed surface of the first wall is shown in Figure 5. The three groups of thermocouples consisted of (1) 4 surface thermocouples under pads on the double wall side; (2) 4 thermocouples without pads on the double wall side; (3) 4 surface thermocouples under pads on the single wall side.

Figure 9, taken at 55 min of test time, shows burning of the single wall portion. Some flame and gray smoke are visible at top of the double wall portion. Flame penetration had taken place at the top of the double

wall portion, but had not yet penetrated to the unexposed surface of the double wall. The failure time of the double wall portion was estimated to be 1 hr 02 min when the unexposed gypsum board was losing contact with the wood studs. Figure 10, taken at approximately 1 hr 15 min of test time, shows the exposed side of the assembly after it was moved from the furnace while water was being applied from a fog nozzle.

7.0 DISCUSSION

The fire endurance of the single wall was 43 min by temperature failure.

During the test when the flame penetration, shown in Figure 7, occurred at 47 min of test time, the gas supply to the burners was discontinued and thermocouples were disconnected; however, the combustion of the assembly continued. Figure 9 shows the complete burning of the single wall, while the double wall was still providing a barrier to flame penetration.

In order to estimate the fire endurance of the double wall it was assumed that the fuel contribution from the plywood burning in the wall was approximately the same order as the heat produced by continued furnace operation. The fire endurance time was based on the time when the gypsum board on the unexposed side of the double wall separated from the studs. This occurred at approximately 1 hr 02 min of test time.

The fire endurance of the double wall was significantly less than twice the fire endurance of a single wall, that is, 62 min vs. 86 min. This result is in agreement with three different loaded double wall

tests subsequently performed under Operation BREAKTHROUGH. The results of these four tests and the constructions of these other specimens are shown in Table I and Table II below.

Table I

Comparison of Fire Endurances in Double Wall Tests

Test	Single Wall (min) Measured Fire Endurance Time	Twice Single Wall (min) Fire Endurance Time	Double Wall (min) Measured Fire Endurance Time	Difference % Double Wall / Twice Measured Single Wall
Single-double wall	43	86	62	28
T2	53	106	72	33
T3	69	138	102	26
B1	42	84	73	13

Average --------------- 25

Note: In Table I above, the average difference in fire endurance between twice single wall and double wall is 25%. This only applies when the quality of each wall in a double wall configuration is nearly the same, and generally when the facing surfaces in the air space are composed of incombustible materials. (In another test of a double wall with steel studs, in which the facing walls were of plywood, failure of the second wall occurred within 2 minutes after the first wall failed.)

Table II

Construction of Double Wall Specimens

Wall	Construction
T2	Paper honeycomb core with polyester/glass fiber skins and a sheet of gypsum board glued to each side.
T3	Similar to T2 with an additional layer of gypsum board on the exposed surface and unexposed surface of the double wall assembly.
B1	Steel studs with one layer of gypsum board on each face.

Since the flame-through occurred at the top of the vertical joint of the assembly and then spread downward, the intended comparison of the two adjacent stud spaces with and without fire stop could not be clearly obtained.

As explained previously, the flame penetration occurred at the top of the vertical joint separating the single and double wall portions of the assembly. Since the furnace burners were immediately shut down in the interest of building safety, it was not possible to obtain a direct comparison of the ultimate fire endurance of the two wall configurations. For such a comparison, separate tests of single wall and double wall configuration should be carried out.

REFERENCE

1. American Society for Testing and Materials, 1970
"Standard Methods of Fire Tests of Building Construction and Materials ASTM Designation E 119-70," available from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

APPENDIX I

Log of Test

Observation

Visual Observation

Time Min:Sec	Observation
0:00	Start test
2:00	Paper on gypsum board of the exposed surface burning
2:30	Paper burning completed
10:00	Slight amount of smoke appeared on the unexposed side
13:00	Joints in gypsum board of the exposed surface appear to be opening slightly.
22:30	Beginning of smoke and flaming at joints on the exposed surface
37:00	Strong flaming through joints on the exposed side
39:00	Second gypsum sheet from south on the exposed surface buckling and its joint opening about 1 inch.
42:00	First joint from south opened about 4 inches.
44:00	Second gypsum sheet from south on the exposed surface fell in.
47:00	Flame penetration at the top of the vertical joint of the single-double wall assembly.
47:30	Gas off
55:00	The unexposed surface (plywood) of single wall portion burning completely.
62:00	The unexposed surface (gypsum board) of double wall portion is separating from the studs.

APPENDIX II

SI Conversion Units

In view of present accepted practice in this country in this technological area, common US units of measurement have been used throughout this paper. In recognition of the position of the United States as a signatory to the General Conference on Weights and Measurements which gave official status to the metric SI system of units in 1960, we assist readers interested in making use of the coherent system of SI units by giving conversion factors applicable to US units used in this paper.

Length

1 in. = 0.0254 meter
1 ft = 0.3048 meter

Mass

1 lb = 0.45 Kilograms

Stress

1 psf = 47.88 newton/meter^2
1 psi = 0.332 newton/meter^2
1 plf = 13.49 newton/meter

Temperature

Temperature in °F = 9/5 (temperature in °C) + 32°F

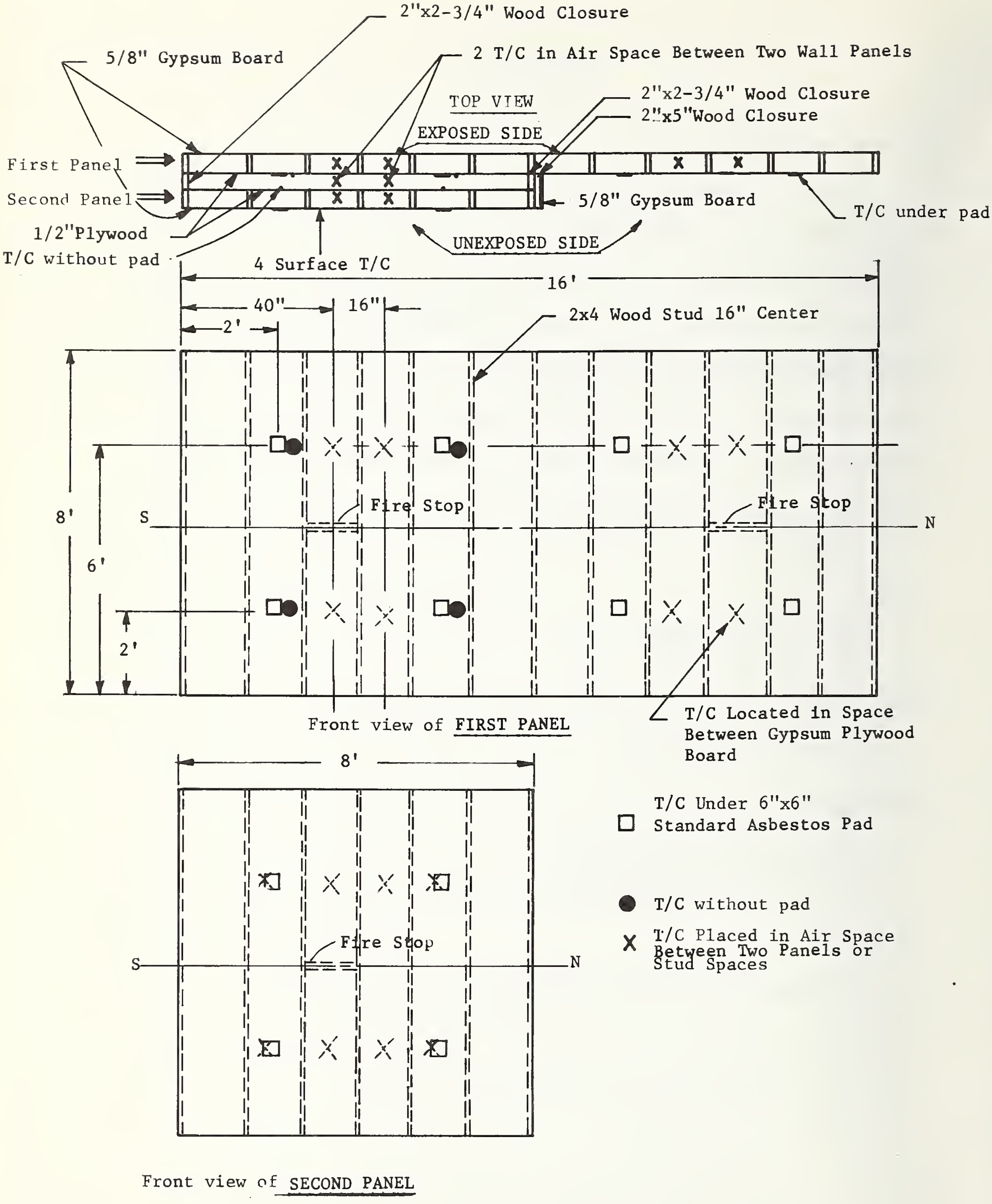

Figure 1. Details of the construction and locations of thermocouples of the specimen.

g. 2 Unexposed surface of the complete wall assembly mounted in the furnace and connection of the thermocouples.

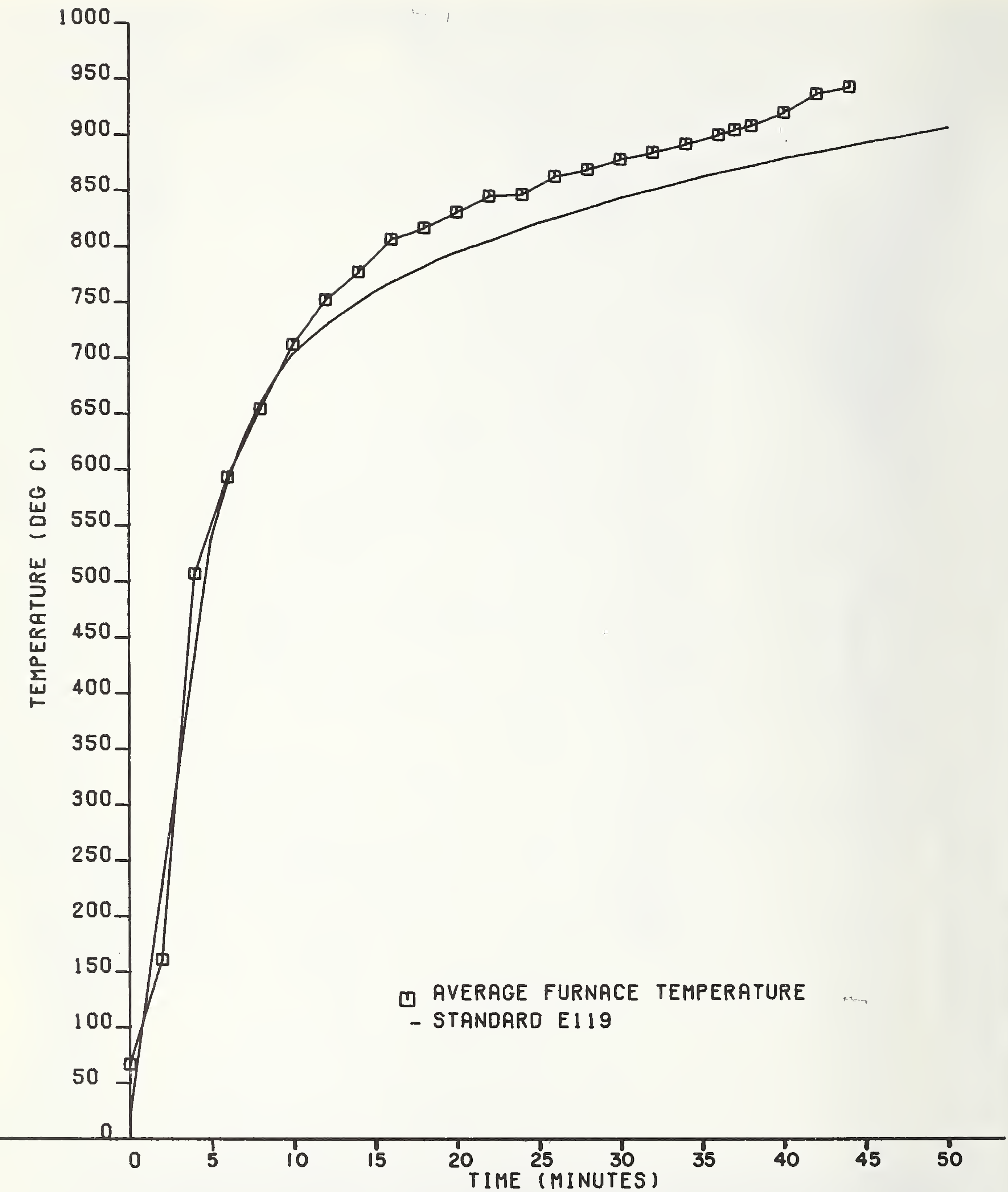

Figure 3. Average Furnace Temperature for Test Compared With Standard E119

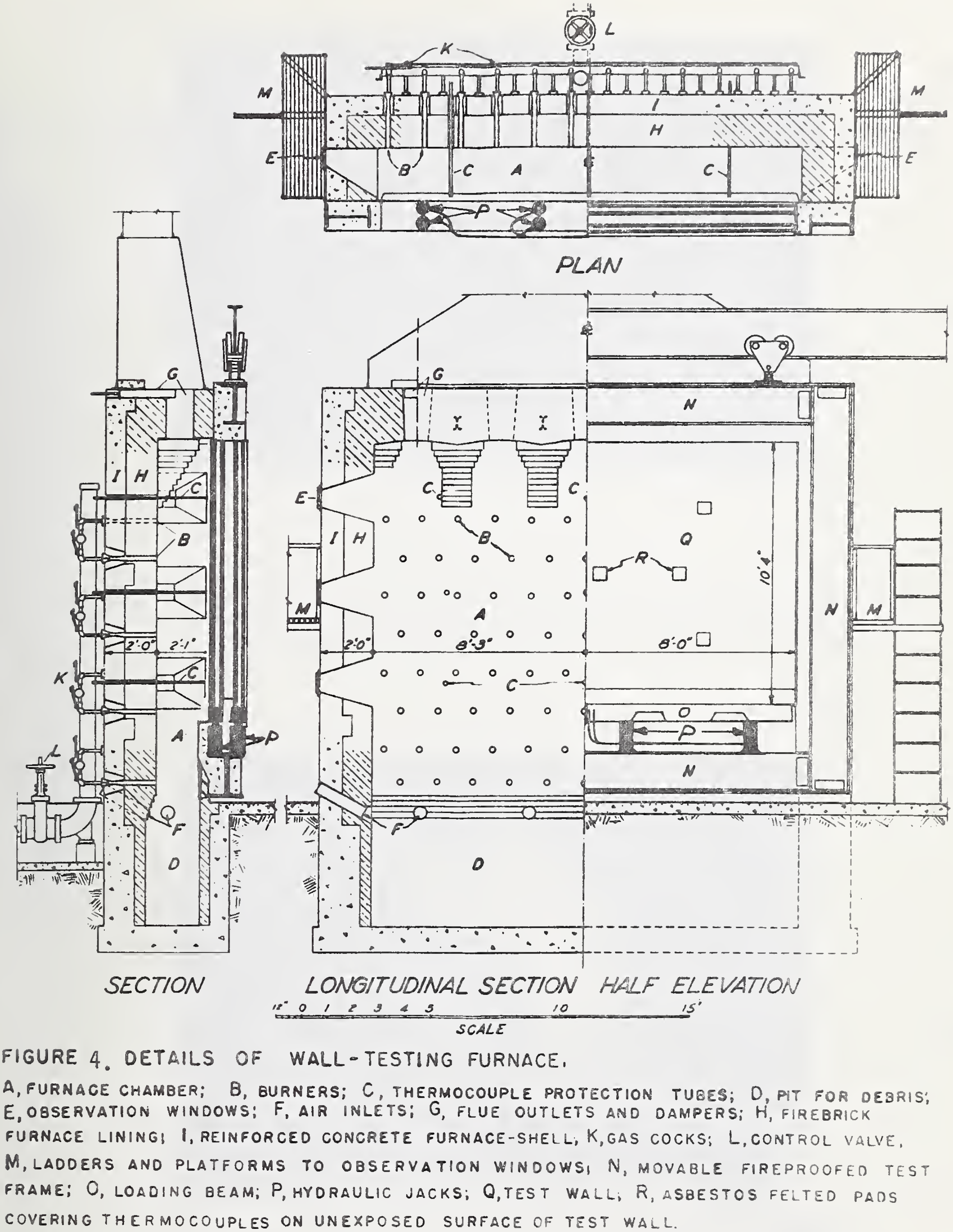

FIGURE 4. DETAILS OF WALL-TESTING FURNACE.

A, FURNACE CHAMBER; B, BURNERS; C, THERMOCOUPLE PROTECTION TUBES; D, PIT FOR DEBRIS; E, OBSERVATION WINDOWS; F, AIR INLETS; G, FLUE OUTLETS AND DAMPERS; H, FIREBRICK FURNACE LINING; I, REINFORCED CONCRETE FURNACE-SHELL, K, GAS COCKS; L, CONTROL VALVE, M, LADDERS AND PLATFORMS TO OBSERVATION WINDOWS; N, MOVABLE FIREPROOFED TEST FRAME; O, LOADING BEAM; P, HYDRAULIC JACKS; Q, TEST WALL; R, ASBESTOS FELTED PADS COVERING THERMOCOUPLES ON UNEXPOSED SURFACE OF TEST WALL.

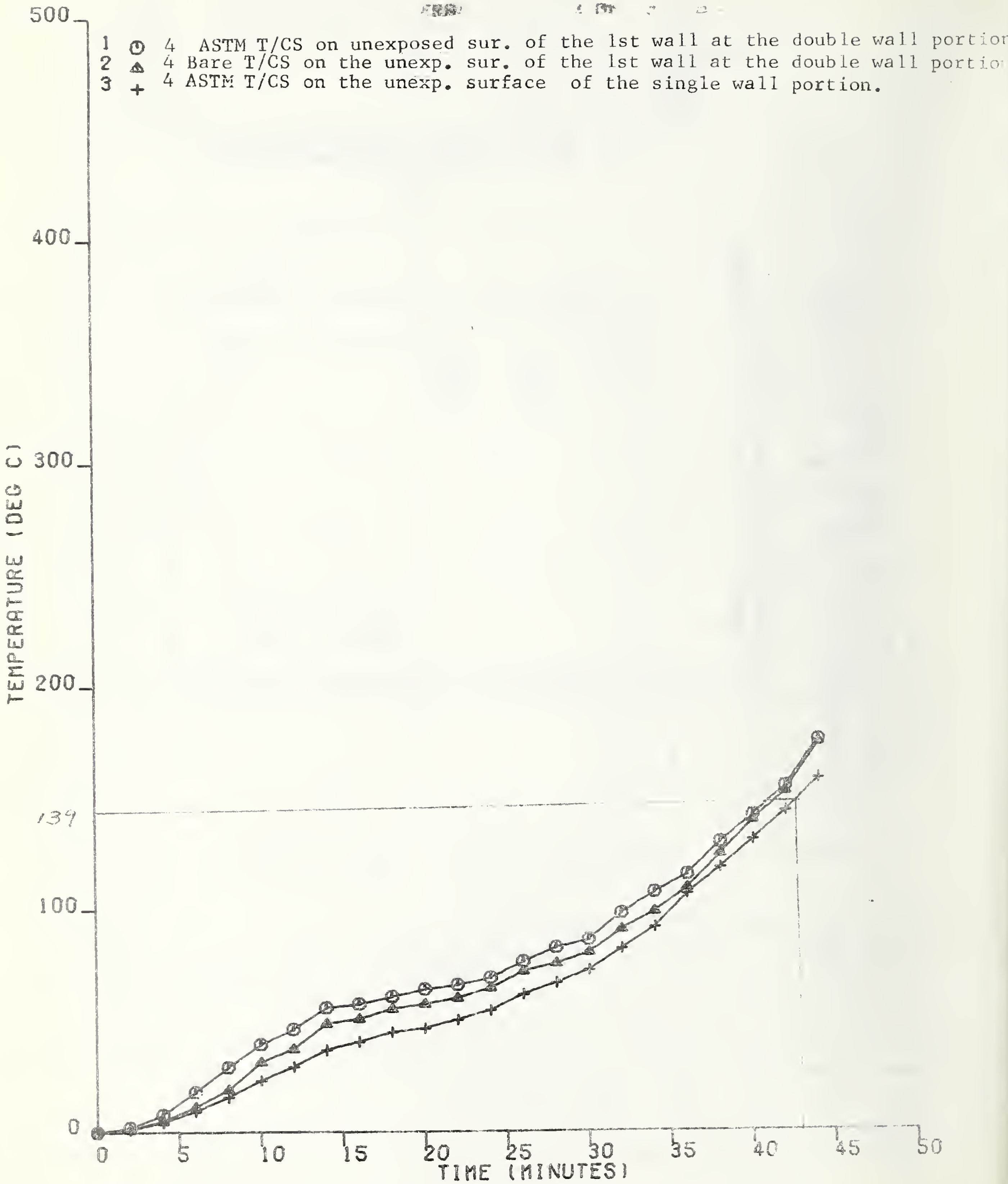

Figure 5. Comparison of Average Temperature Rises of 3 Groups of Thermocouples

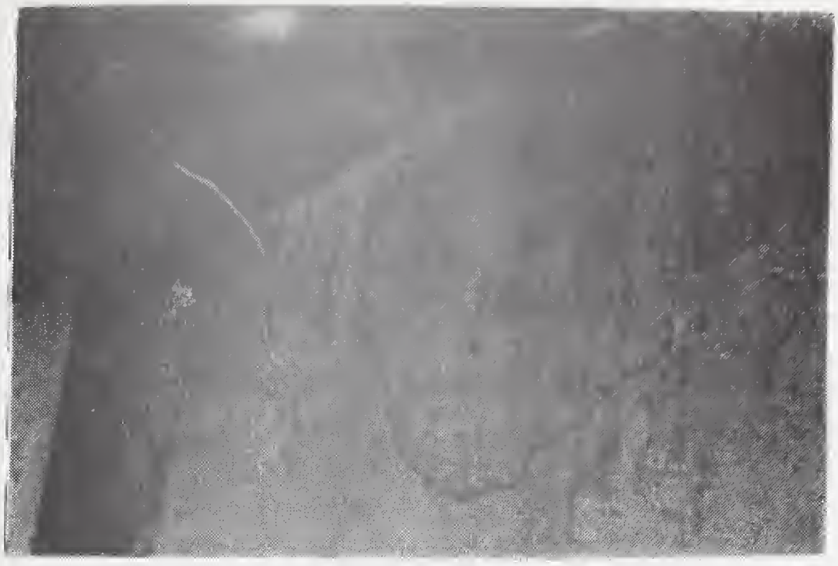

Fig. 6 Location of the flame through just before the instant of the flame through. Gray smoke may be noticed at top of the double wall portion.

Figure. 7 Location of the flame through.

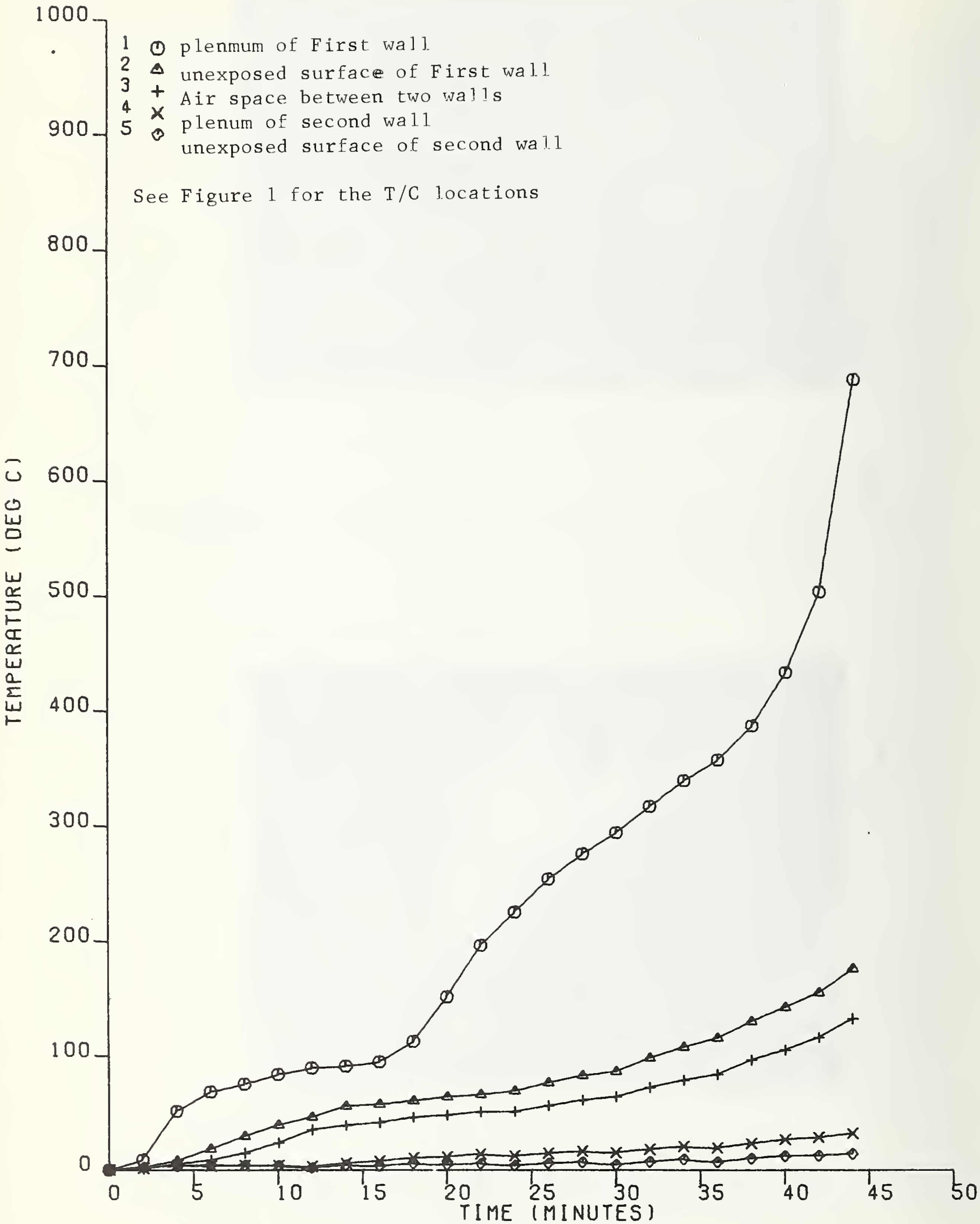

Figure 8. Average Temperature Rise Across Double Wall Panel For Test

Fig. 9 Complete burning of the single wall while the unexposed surface of the double wall intact.

Fig. 10 Exposed side of the wall assembly after it was removed from the furnace.

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15. SUPPLEMENTARY NOTES

16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)

As a part of the testing and evaluation activities in Operation BREAKTHROUGH, a standard fire test conforming to ASTM E 119 was performed at the National Bureau of Standards on a wall assembly where half represented a nonbearing single exterior wall (as found in single family detached housing) and the other half represented a nonbearing double wall assembly for an interdwelling separation which would occur at the interface of two parallel adjacent modules. Each wall contained a layer of gypsum board as an interior (room) surface and a layer of plywood as an exterior surface, and was framed with nominal 2 x 4 in. wood studs on 16 in. centers. No structural load was applied during the test.

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17. KEY WORDS (Alphabetical order, separated by semicolons)

Fire endurance; Fire test; Housing systems; Interdwelling wall; Operation BREAKTHROUGH; Single wall

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